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The Importance of Technical Reachback in the Adjudication of Radiation Alarms

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The Importance of Technical Reachback in the Adjudication of Radiation Alarms

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Abstract. The large-scale deployment of radiation sensors at borders, ports-of-entry and other locations carries two disparate priorities: the reliable detection and identification of threat materials and the rapid characterization of non-threat materials comprised of naturally occurring radioactive materials (NORM) and legitimate radioactive materials in streams of commerce. These priorities are partially achieved through the technologies contained in the detection systems and the procedures developed for their operation. However, questions and ambiguities will occur. Without established capabilities and procedures for the operators of these detector systems to "reach back" to trained spectroscopists and appropriate subject matter experts, the system will likely experience an unacceptable number of response operations and delays resolving alarms. Technical reachback operations need to be able to address the priorities discussed above while causing minimal perturbations in the flow of legitimate streams of commerce. Yet when necessary, reachback needs to be able to rapidly mobilize the appropriate response assets.

1. Introduction

The possibility of nuclear terrorism has been with us almost since the dawn of the nuclear age. Awareness of the threat has increased, especially with respect to Usama bin Ladin and al-Qaida, who reportedly tried to acquire fissile and/or other radioactive materials, apparently since at least the early 1990s. In 1998, bin Laden declared the acquisition of weapons of mass destruction (WMD) a "religious duty."[1] Few analysts doubt that some terrorists would indiscriminately kill thousands or tens of thousands if such an attack could be mounted, as evidenced by the 1993 attempt to topple at least one of the World Trade Center towers. The nuclear terrorism threat will be with us for a long time—the hundreds of metric tons of weapon usable nuclear materials that exist cannot be "unproduced," knowledge of nuclear explosives principles cannot be "unlearned," and there will not soon be a lack of adversaries that would likely use such a capability if they had it. The enduring nature of this threat cannot be overstated—just as the threat did not first emerge on 9/11, mitigation of the threat requires an enduring and diligent effort whose seeds are still being planted.

The worldwide concern over the possibility of nuclear terrorism and also possible radiological attacks (which would likely be limited to far fewer casualties but could nonetheless have significant environmental, economic and political consequences) has prompted numerous countermeasures that are in effect a "defense in depth" against the threat. Among these countermeasures is the increasing use of radiation detectors in Preventive Radiological/Nuclear Detection (PRND) applications.

[1] *Time Magazine*, December 24, 1998 (Interview)

These detectors are deployed in a world awash with legitimate sources of radiation, and detectors will thus register numerous above-threshold alarms that are non-nefarious in nature. A graded response to PRND alarms is necessary. This paper discusses some key aspects of the U.S. PRND architecture, along with some exemplary radiation detection incidents that illustrate the utility and importance of technical reachback.

Detection of black market fissile materials has always been an important component of a defense-in-depth against nuclear terrorism. As detection technologies improve, and given the interest in acquiring WMD and the willingness to use them if acquired, the detection countermeasure is more important than ever.

2. The increasing use of radiation detectors in Preventive Radiological/Nuclear Detection (PRND)

There are an increasing number of radiation detection systems being deployed in the United States and throughout the world at borders, ports, airports and metal processing facilities. The primary purpose of these systems is to detect illicit radioactive material that could be part of a nuclear or radiological attack plan or operation. These detection systems have also proven helpful in detecting health/safety hazards, e.g., radioactively contaminated foodstuffs and orphan sources or other radioactive contamination in scrap streams.

Potential threat and health and safety risk materials are a miniscule fraction of legitimate, benign radioactive material movements. To recognize genuine threats and expeditiously resolve benign radiation detection events, we must understand the world "the way it is" with regards to radioactive materials in commerce.

3. The Radioactive World - causes for detection alarms

A wide variety of circumstances can result in radiation detector alarms:

- Naturally occurring radioactive materials (NORM), including Technologically Enhanced NORM (TENORM). These are frequently encountered in streams of commerce.
- Legitimate radioactive materials shipments involving industrial, medical or scientific radiation sources.
- Medical radioisotopes (radiopharmaceuticals) are also frequently encountered in shipment, in radiopharmaceutical patients, or in waste shipments.
- Radioactively contaminated items, or radioactive material that has undergone a loss of control (typically orphan sources in scrap), may also be the cause of radiation detection alarms. These incidents may either be accidental or the result of illegal disposition.
- Self-luminescent items such as clocks and dials employing radium-based paints (often shipped as souvenirs and antiques).

- Detection equipment malfunction, detector interferences and human error can also cause detection alarms.

- Possibly nefarious illicit trafficking of nuclear or radiological materials. This circumstance is "low probability" but with a potentially high consequence if incorrectly dismissed as non-nefarious.

4. Radioactive materials shipments are common

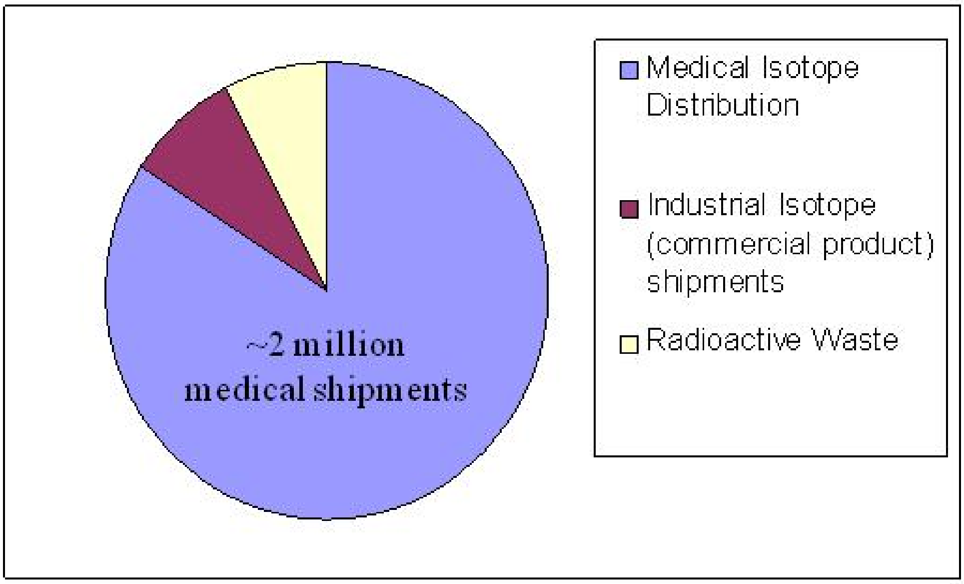
About 3 million packages of (Department of Transportation regulated) radioactive materials were shipped in 2005 in the United States alone. This is a small fraction of the approximately 400 million packages of hazardous materials shipped in the U.S. that same year.

U.S. radioactive shipments can be grouped into the following categories:
- Industrial isotopes
- Nuclear medicine isotopes
- Nuclear fuel cycle materials
- Nuclear waste
- Government (Department of Defense/Department of Energy) movements.

The **number** of shipments of radioactive material is dominated by medical isotopes (see Figure 1). The vast majority of **radioactivity** in radioactive material shipments is due to imported Co-60 for use in industrial irradiators.

All industries have a "life cycle" involving few shipments of high activity, and a much higher number of shipments to (and among) end users involving much lower levels of activity.

Figure 1. Relative numbers of radioisotope shipments in U.S. (2005)



5. Graded response to radiation alarms

The world abounds with radioactive material. Some of this material moves through streams of commerce and will pass in proximity to deployed protective nuclear/radiological detection systems. Thus, detectors will encounter above-threshold levels of radiation from these materials, but as noted, the vast majority of these alarms are in fact innocuous in nature.

This reality calls for a graded approach to adjudication and appropriate response. Easily identified and "low concern" alarms can generally be resolved quickly and locally by personnel at the detection site, although training and quality assurance processes are crucial to ensuring that local adjudication is done correctly and appropriately errs on the side of caution. Detection scenarios that are cause for additional concern should be escalated using a "reachback" capability that applies additional expertise and technology to adjudicate the alarm. Depending on the number of detectors, the streams of commerce being examined, risk analysis and other factors, it may be appropriate to employ tiers of reachback adjudication, as is found in the evolving U.S. system.

6. The U.S. utilizes a National Reachback system

The U.S. employs a "national reachback" system of radiation detection alarm adjudication that basically utilizes two tiers of spectroscopic experts from U.S. scientific laboratories (as illustrated in Table 1):

- Regional level with expertise from DOE national laboratories
- National level with expertise from DOE/NNSA weapon laboratories

One major component of the system is managed by the Department of Homeland Security's Domestic Nuclear Detection Office and its Joint Analysis Center, utilizing national laboratory spectroscopic expertise and nuclear smuggling/ threat assessment expertise from the DHS Nuclear Assessment Program to coordinate, integrate, and fuse:

- Spectroscopic analysis
- Nuclear smuggling, R/N threats, potential WMD terrorist groups, etc
- Other subject matter experts as needed

7. National reachback response overview

A radiation detection alarm occurs at a PRND portal monitor at a U.S. port of entry. The conveyance is subjected to on-scene secondary screening using a second portal monitor and a radioisotope identification device (RIID).

If the incident cannot be resolved locally at the port of entry, incident information including RIID spectra, portal trace data, manifests and possibly other data is sent electronically to a primary reachback location staffed by forensic scientists with training in spectroscopic analysis, who also have access to additional manifest and shipping information. Under some "trigger" conditions (e.g., unresolved source of neutron radiation) or if there are any residual concerns, the primary reachback site will elevate the incident to the national reachback level.

When referred to DHS's national reachback capability, the incident information is quickly reviewed for completeness, and on-call spectroscopists (and other subject matter experts as needed) are contacted. A telephone conference call is scheduled among the subject matter experts. The analysis is conducted and coordinated in the conference call. The expert's conclusions and recommendations are then conveyed back to primary reachback (typically within one hour of activation), which coordinates final disposition at the port of entry.

8. The National Reachback program includes crucial QA components

In addition to the 24/7 operational capability summarized above, the national reachback capability includes equally important quality assurance and data mining/trend analysis efforts intended to:

- Refine our understanding of streams of commerce and radioactive materials in the real world.
- Learn and share information from experience (recognize similar incidents).
- Identify trends that can be helpful in future alarm adjudications.
- Train, practice and certify (at all levels of the reachback architecture).
- In a spiral development cycle, **continuously tune the detection architecture** to improve efficiency and effectiveness.

An important goal of the tiered reachback architecture and its QA components is to develop and communicate situational awareness across the overall detection enterprise. The personnel involved will have the broad experience of resolving alarms throughout the system. This includes disseminating alarm resolution knowledge and awareness to "front-line" detector locations, expanding their effective experience and allowing more alarms to be resolved locally.

9. Example incident – neutron alarms in scrap

9.1 Alarm

Scrap materials have caused a portal monitor neutron alarm. There are no readily identifiable gamma rays in the spectra. The presence of threat material cannot be discounted. Due to the nature of the commodity, the scrap materials are not easily devanned from a railcar or container (e.g., Figure 2 provides a visual insight into the difficulty of devanning).

Figure 2. Scrap materials being shipped

9.2 Resolution

Experts can analyze the data for other indicators that reduce the likelihood of fissile threat materials in the load, but there is a significant intrinsic problem. If the gamma-ray spectra extends to high enough energies, one can postulate the presence of an americium-beryllium (Am-Be) neutron source through the presence of the $^{9}Be(\alpha,n)^{12}C$ 4.43-MeV gamma ray and its escape peaks at 3.92 and 3.41 MeV.

An alternative means of resolving this type of incident is the availibility of neutron multiplicity measurements to differentiate between fission (potential threat) and "alpha-n" neutrons. However, these devices are expensive and most of them are not portable.

In many cases like this that have generated concern, an Am-Be source was found in the load or was indicated by the detection of $^{9}Be(\alpha,n)^{12}C$ gamma rays.

10. **Example incident – calcium monophosphate**

10.1 Alarm

A radiation portal gamma alarm has occurred on a shipment of a feed-additive commodity, manifested as calcium monophosphate. Secondary inspection with a RIID suggests the possible presence of enriched uranium.

10.2 Resolution

Phospate is mined throughout the world. Many phosphate deposits contain (depending on economics) recoverable quantities of uranium. At various locations and times uranium has been recovered from phosphate mining operations. The phosphate leaching/milling process often involves sulfuric acid. Sulfuric acid is also used to leach uranium from ores.

Leaching the phosphate will carry along uranium in the concentrate. Also as a result of the leaching process, the uranium has its decay daughters washed away. One of these daughters, protactinium 234m (Pa-234m), is the source of the 1001-keV gamma-ray line that is commonly used to measure the presence of U-238 (which lacks easily measurable gamma rays).

This reduction in the uranium daughter results in the RIID's software/firmware indication of enriched uranium.

11. Uranium – both an element of concern and a commonly encountered radioactive material in commerce

Uranium is transported as a fuel cycle commodity in both natural (unenriched) and enriched forms. It is frequently shipped as uranium ore concentrate (also refered to as uranium ore or yellow cake) with chemical forms of U_3O_8 or uranyl peroxide (UO_4). It is also encountered as calcined uranium (UO_2) in the form of oxide powder, fuel assemblies, or fuel pellets.

Uranium hexafluoride (UF_6) is also shipped between nuclear fuel cycle facilities, as is to a lesser extent uranium trioxide (UO_3), uranium tetrafluoride (UF_4), and uranyl nitrate.

Depleted uranium is also encountered in streams of commerce as radiation shielding material—given its high density and low radioactivity, it is commonly used as gamma radiation shielding for radiography projectors (e.g., Ir-192) and in the shipment of other intense sources.

Occasionally highly enriched uranium (HEU) target material or fission chambers containing HEU are shipped commercially.

Distinguishing these many common types of uranium shipments from potential threat material is one important facet of the detection alarm adjudication system.

12. Summary

There is a widespread and increasing use of radiation detectors in an environment characterized by a high frequency and wide variety of legitimate radioactive materials that are naturally or legitimately found in streams of commerce.

This must be balanced with concerns regarding potential nuclear or radiological terrorism, and health/safety risks associated with undetected radioactive contamination. There are numerous illicit nuclear or radiological trafficking incidents each year; many prove to be of little significance with regard to genuine terrorist plans or operations but the level of trafficking emphasizes the concern regarding the overall threat.

It is important that radiation detection capabilities include protocols for technical reachback and continuous spiral development in adjudicating detection alarms.

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